WRP Technical Note HY-IA-2.3
March 1997

Future Needs in Wetland Hydrology and Hydraulics

PURPOSE: Future research needs are identified for improving computer simulations of wetland hydrology and hydraulics. Potential applications of modeling to determine simplified techniques and relationships are also provided.

MODEL IMPROVEMENTS: The Wetlands Dynamic Water Budget Model (WDWBM) was based on a number of models in common use and incorporates many of these models' theories and approaches. An underlying objective was to keep the model relatively simple and efficient, so that it could simulate year-to-year variations. While many of the future model modifications will arise from applications, several areas of study have been identified to improve model accuracy, efficiency, and reliability.

The current version of the vertical processes module uses a Priestley-Taylor (1972) description of evapotranspiration. This procedure requires knowledge of only air temperature and net solar radiation. More sophisticated methods for estimating evapotranspiration could be examined to assess their effectiveness and data requirements. The vertical processes module assumes a saturated flow condition for infiltration across the ground surface. A more exact physical description of unsaturated infiltration could be incorporated into the model.

A number of methods can be used to determine hydraulic conductivity when simulating groundwater flow. It would be useful to examine the effects of these methods on model results. An explicit solution algorithm has been used for all modules. It would be useful to examine the potential computation savings and effects on model accuracy of using an implicit algorithm for at least the vertical processes module, which can have the most severe stability constraints. Model geometry could be calculated using a digital elevation model, from which the nodal and link properties could be determined.

Future Applications: To date, the WDWBM has been successfully applied to riverine and estuarine wetlands. As a consequence, it is felt that the surface water routines have been adequately verified. In order to more completely test the accuracy and adequacy of the remaining process modules, wetlands characterized by primary interactions between horizontal groundwater flow, infiltration, and evapotranspiration need to be examined. An excellent example of such wetlands are the prairie potholes on the northern plains. Finally, the interactions between all the modules can be studied by applying the water budget model at the landscape or watershed basinwide level. At this level, the relative importance of each of the water budget components will vary both spatially and temporally.

Simplified Methods: The successful application of the WDWBM to the Black Swamp area of the Cache River in Arkansas (Figure 1) has produced a 4-year database of surface water elevations and flows throughout the wetland. This database, along with field data collected during the Wetlands Research Program, provides the opportunity to develop and test simplified methods of wetland hydrology and hydraulics (H&H) analyses. For example, correlation functions of computed surface water elevations with available U.S. Geological Survey (USGS) gauge data at Patterson, James Ferry, and Cotton Plant can allow future evaluation of the impacts of flow alteration on the hydroperiod within the Black Swamp, and development of a historical database of hydroperiods using the long-term gauge record available at Patterson. Several examples of these regressions are provided in Walton and others (1995).

Report Documentation Page			*Form Approved* *OMB No. 0704-0188*
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.			
1. REPORT DATE **MAR 1997**	2. REPORT TYPE		3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Future Needs in Wetland Hydrology and Hydraulics**			5a. CONTRACT NUMBER
			5b. GRANT NUMBER
			5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)			5d. PROJECT NUMBER
			5e. TASK NUMBER
			5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Army Engineer Waterways Experiment Station,3909 Halls Ferry Road,Vicksburg,MS,39180-6199**			8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSOR/MONITOR'S ACRONYM(S)
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**			
13. SUPPLEMENTARY NOTES			
14. ABSTRACT **see report**			
15. SUBJECT TERMS			
16. SECURITY CLASSIFICATION OF: a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	17. LIMITATION OF ABSTRACT / 18. NUMBER OF PAGES **5** / 19a. NAME OF RESPONSIBLE PERSON

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Regression of the Patterson gauge versus the B5 gauge, using a 2-day time lag, is presented in Figure 2. A companion analysis of hydroperiod (continuous days above a specified flood stage) at the Patterson gauge is compared with the resulting stage-duration at the B5 gauge in Table 1.

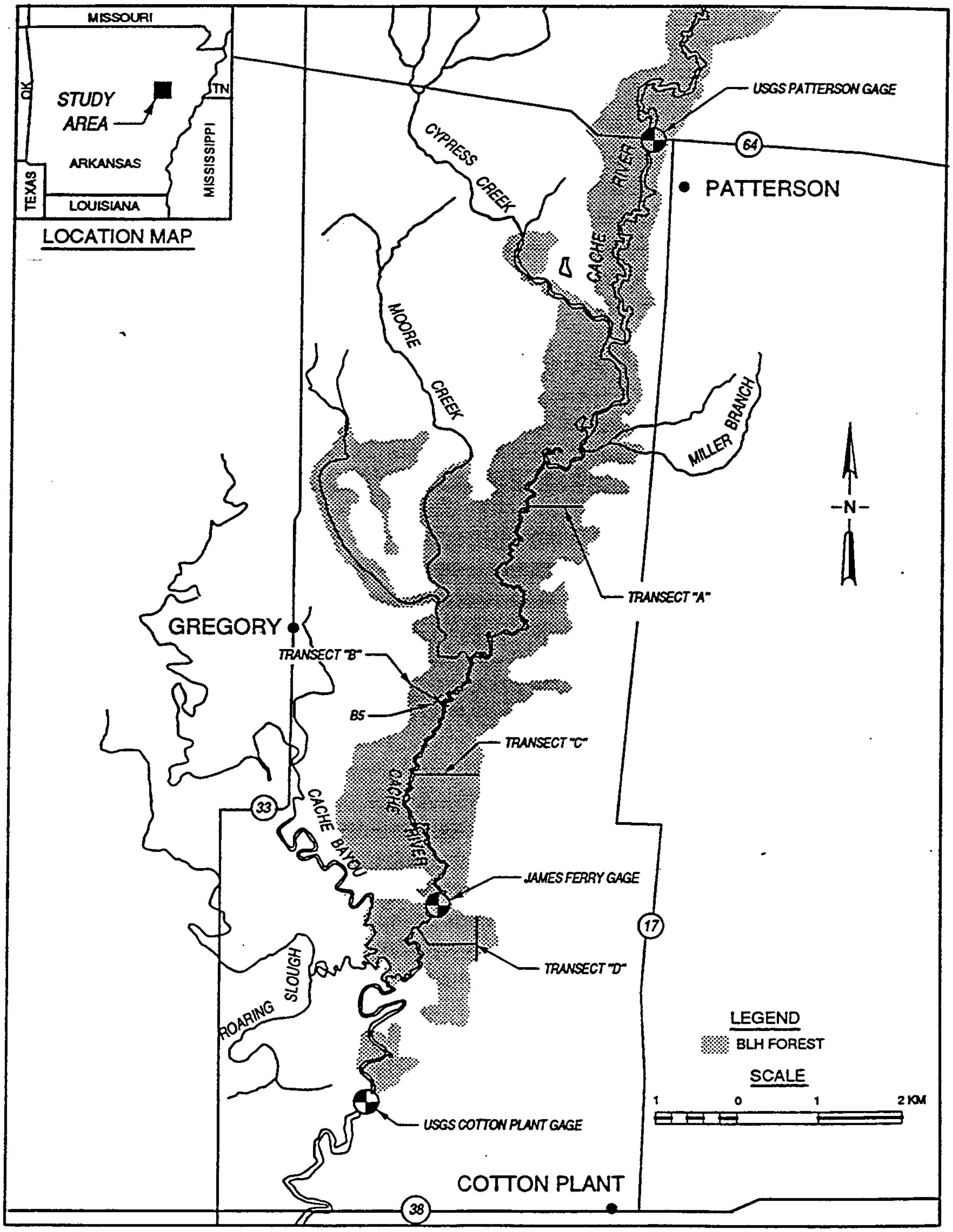

Figure 1. Black Swamp Wetland on the Cache River in Arkansas

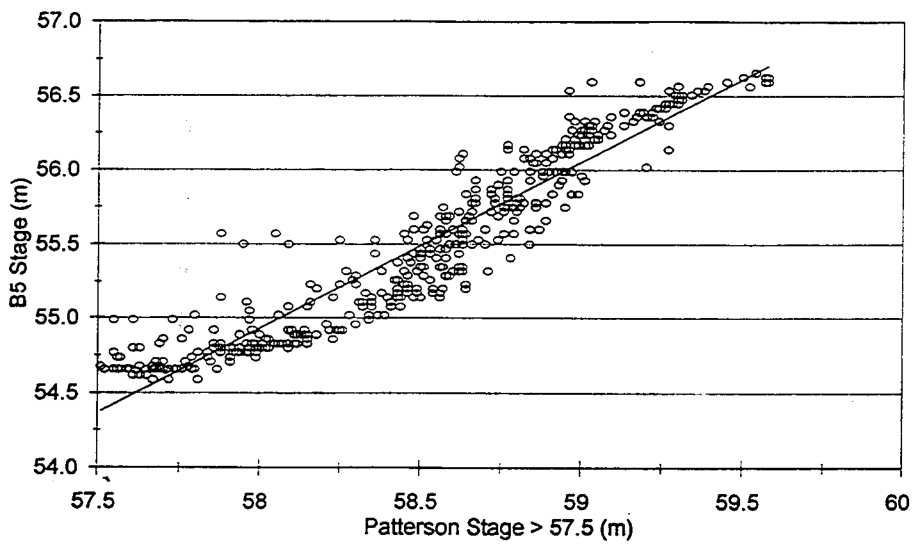

Figure 2. Regression analysis between Patterson and B5 data using a 2-day time lag

Table 1
Hydroperiod at Station B5 and Patterson

B5			Patterson		
Elevation, m	Days	Mean	Elevation, m	Days	Mean
54.6	511	170	56.7	510	510
54.8	382	42	57.8	379	31
55.0	303	60	58.2	300	33
55.2	258	43	58.5	249	24
55.4	221	36	58.5	218	18
55.6	175	29	58.7	171	17
55.8	134	26	58.8	129	16
56.0	102	25	58.9	100	16
56.2	57	14	59.0	50	10
56.5	23	11	59.3	19	6

Examination of this table suggests that there is a consistent correlation between the hydroperiod of a given storm event recorded at Patterson and the resulting stage and hydroperiod experienced at the B5 gauge. In addition, there is significant backwater or storage effect due to the constriction of the flow between James Ferry and Cotton Plant. This is seen in the increased hydroperiod at the B5 gauge. The important point to be made here is that the computed surface elevation database can be used to develop similar correlation functions at any location within the Black Swamp. As a result, more complete and

longer term information on stage and hydroperiod at the other three Cache River research transects can be made available.

A simplified method for performing a wetlands water budget analysis and determining the relative importance of H&H processes can be based on the following balance equation:

$$Q_i + R + G = Q_o + ET + I \tag{1}$$

where

Q_i = surface water flow into system
R = direct rainfall on wetland
G = groundwater discharge to wetland
Q_o = surface water flow out of system
ET = evapotranspiration from wetland
I = infiltration to the groundwater

For many wetlands, these variables can be estimated using simple methods or available data, or both. Surface water inflows can be determined from upstream gauges or from published statistics of river flows. If the basin is ungauged, then it is possible to estimate flows using data from nearby gauged basins and multiplying by the ratio of drainage basin areas, or using published regression analyses (available for many states from the USGS). Downstream flows can be determined using the same approaches, or by using data from control structures such as weirs, gates, and culverts. Flows can be converted to annual volumes/unit area by summing the flow over 1 year and dividing by the surface area of the site.

Rainfall data are available from nearby gauges or published summaries (for example, annual rainfall maps from the National Oceanic and Atmospheric Administration). Potential evapotranspiration data can be obtained from a number of sources or calculated from atmospheric parameters such as air temperature and net solar radiation, using formulas such as the Priestley-Taylor method.

Groundwater discharge can be estimated from potentiometric head data using Darcy's Law. Maximum potential infiltration can be estimated from percolation tests, sometimes published in local soils reports, or from measurements or estimates of saturated hydraulic conductivity based on only a crude knowledge of local soil types. An upper bound can be calculated by multiplying one-half times the saturated hydraulic conductivity by the amount of time the site is estimated to be inundated or receiving rainfall. It should be recognized that this may represent an extreme upper bound as it does not consider other factors, such as the soil becoming fully saturated and unable to receive additional water unless some soil water is removed. It is also important to recognize that Equation 1 can be used to estimate the magnitude of a process with no data, or to provide an alternative estimate for a process (usually groundwater discharge or infiltration) that may be poorly estimated, provided estimates are available for ***all*** of the other processes.

To decide whether each process is important in the hydrology of the wetland being evaluated requires a knowledge of the errors in these estimates and a decision as to when one process dominates another. Typically, riverflows can be measured to 5 to 10 percent accuracy if good gauge data are available. Measurements and estimates of the other variables are probably less accurate in most cases. A first-order

criterion might be that one process is not significant if it provides less than 10 percent of the flow of any other component.

To illustrate this procedure, the Cache River database was used to develop an approximate annual water budget (Table 2).

Table 2
Annual Water Budget for the Black Swamp Wetlands

Variable	Annual Volume/Unit Area, m
Inflow	14
Outflow	16
Rainfall	1
Evapotranspiration	1
Groundwater discharge	<1
Infiltration	<1

Infiltration was estimated at about 6 m, assuming reasonable values for saturated hydraulic conductivity and inundation of the wetlands about one-third of the time. However, this value is probably greatly overestimated, as it neglects the saturated soil conditions that would frequently result under these conditions. Therefore, a more reasonable value, shown in Tables 1 and 2, was used based on satisfying the water budget of Equation 1. From this analysis, using a 10-percent criterion, one could conclude that on an annual-average basis, only river inflows and outflows are of major hydrologic importance in the Black Swamp. This analysis could be expanded to consider the relative importance of processes at other time scales (perhaps seasonal) and to examine other types of wetlands.

CONCLUSION: Future research needs have been presented which would improve upon the predictive capability of the WDWBM. In addition to describing potential model improvements and future applications, a guide has been presented for using the water budget model as a test platform for the development and verification of simplified methods of wetland H&H analyses. Examples of simplified methods for 1) determining stage and hydroperiod throughout the Black Swamp of the Cache River and 2) performing approximate water budgets for wetlands and determining the relative importance of individual H&H processes have also been presented.

REFERENCE:

Walton, R., Martin, T. H., Chapman, R. S., and Davis, J. E. (1995). "Investigation of wetland hydraulic and hydologic processes, model development, and application," Technical Report WRP-CP-6, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

POINT OF CONTACT FOR ADDITIONAL INFORMATION: Mr. Jack Davis, U.S. Army Engineer Waterways Experiment Station, ATTN: CEWES-CD-SE, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, phone: (601) 634-3006, author.

Dr. Raymond Walton, WEST Consultants, Inc., 2101 4th Ave., Suite 1050, Seattle, WA 98121-4431, co-author.